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CASE REPORT

CONSIDERATION OF SPORT DEMANDS FOR AN 18-YEAR-OLD LACROSSE PLAYER WITH RECALCITRANT SYMPTOMATIC SPONDYLOLYSIS: A CASE REPORT

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ABSTRACT

Background and Purpose: Spondylolysis is an anatomical defect or fracture of the pars interarticularis and encompasses almost half of all cases of low back pain in adolescent athletes. Most athletes return to sport with conservative treatment, but it is possible that consideration of sport demands may further improve rate of successful return. When surgery is performed, complication rate is high, so all conservative measures should be explored before considering surgical intervention. The purpose of this case report is to present a program where demands of sport were considered and allowed successful return to sport for a subject with recalcitrant symptomatic spondylolysis that had failed to respond to prior treatment.

Case Description: An 18-year-old lacrosse player with a history of recalcitrant symptomatic spondylolysis that failed three courses of conservative treatment and had been unsuccessful in returning to sport. A multi-phase program with a focus on multi-planar and full kinetic chain activities that addressed the nature of the sport demands is described, along with improvements in pain level, strength, range of motion, and subjective outcome scores.

Outcomes: The subject was able to successfully return to sport after 10 weeks of physical therapy and complete the remaining few months of his lacrosse season without reinjury. Range of motion and strength testing was markedly improved upon discharge. The subject's Modified Oswestry Disability Index improved from 16% to 0% and his pain level did not rise above 2/10 with any sport activity upon return.

Discussion/Conclusions: Although return to sport rates following spondylolysis in young athletes is high, this case report demonstrates that a consideration of sport demands may increase return to sport rates in athletes that do not respond to standard care and prevent surgical intervention.

Level of Evidence: Level 4, single case report.

Key Words: spondylolysis, adolescent athlete, low back pain, lacrosse

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BACKGROUND

Spondylolysis is an anatomical defect or fracture of the pars interarticularis of the vertebral arch, commonly occurring in the lumbar spine.[1–4] Spondylolysis occurs at a rate of 3 to 10 percent in the population, although is not always symptomatic.[5–7] Spondylolysis accounts for anywhere from 28% to 47% of all low back pain in the adolescent athlete.[7–9] Incidence is especially high in young athletes participating in sports requiring repetitive hyperextension and rotation with hyperextension due to the stress placed on the pars interarticularis in an immature spine.[2,3,10–12] High incidence sports that require these demands include gymnastics, football, soccer, tennis, baseball, volleyball and swimming.[3,11–15]

Lacrosse shares similar characteristics with some of these sports. Throwing or shooting a lacrosse ball effectively requires quickly transferring energy from the lower body through the trunk to the upper body through a rotational pattern for maximal speed.[16,17] Sports such as tennis and baseball require similar repetitive mechanics in which the spine is required to move quickly from a position of hyperextension to flexion while rotating.

The key phases of a lacrosse throw, as defined by Vincent et al., are the crank back phase, the acceleration phase, and the follow through phase.[18] In the crank back phase, the shooting shoulder and trunk rotate away from the target as the front foot contacts the ground. In the acceleration phase, the velocity of movement at the pelvis, trunk, and upper arm increase to prepare for ball release. During the follow through phase, deceleration occurs as the shooting shoulder crosses over the pelvis.[18] As the crank back phase ends and the acceleration phase begins, the shoulders are maximally rotated away from position of the pelvis in the transverse plain. As the follow through phase ends and the body is decelerating, there is another period of maximal angular difference in the transverse plane between the shoulders and pelvis. These two periods of excessive rotation combined with the high rotational velocity of completing a throw can create increased stress through the entire kinetic chain, especially through the lumbar spine.[18,19]

Core musculature is crucial for lumbar spine stability with dynamic movements. Without muscular support, spinal buckling occurs at compressive forces well below those typically experienced during activities of daily living.[20] With poor neuromuscular control of core musculature and repetitive external load, the pars interarticularis receives a high level of stress which contributes to the development of stress fractures, especially in athletes with immature skeletons.[1,10,13] It is thought that a lack of core stability may be related to lower quarter injury and coordinated trunk muscle strengthening in all three planes of motion may increase core stability and reduce injury risk.[19,21–23]

Treatment for spondylolysis is primarily conservative, consisting of rest from sport and aggravating factors, bracing, and physical therapy (PT).[1,2,4,11,13,14,24,25] The PT intervention currently described in the literature is ambiguous yet appears to consist primarily of core and gluteal strengthening and hamstring stretching.[1,2,4,11,13,14,24,25] With conservative treatment, 75% to 96% of athletes are able to return to sport.[1,2,4,11,13,14,24,25] When symptom alleviation and/or return to sport is not achieved, surgery is performed, with anywhere from 85% to 90% of subjects successfully returning to sport.[1,2,11,24] The complication rate following surgery for spondylolysis has been reported between 11% and 20%.[11,24] With such a high reported complication rate, all conservative measures should be exhausted before considering surgical intervention with spondylolysis.

It may possible that a PT approach including kinetic-chain, multi-planar, and sport-specific activities could increase the success rate of conservative treatment, thus avoiding surgery in more athletes. The purpose of this case study is to describe a full body, multi-phase approach to the rehabilitation of an 18-year-old male lacrosse player with recalcitrant symptomatic spondylolysis who had previously failed three courses of conservative treatment.

CASE DESCRIPTION

The subject is an otherwise healthy 18-year-old male lacrosse player with a history of recalcitrant symptomatic right sided L5 spondylolysis. He has completed three separate bouts of therapy over three years, consisting of rest, bracing, and multiple months of PT. The previous PT interventions included primarily hamstring stretching and trunk and gluteal strengthening in the sagittal and frontal planes. His most recent bout of treatment was one year prior. He attended 18 visits over the course of three months. Each time the subject resumed play, sharp right-sided lumbar pain returned in under a week, always during the follow through phase of a right-handed lacrosse throw when he is eccentrically working to control the throw. The subject notes fear of reinjury with lacrosse but is highly motivated to return to sport.

CLINICAL IMPRESSION #1

When considering the kinetic chain movements during a lacrosse throw, the lumbar spine is vital for transferring energy from the lower extremity to the upper extremity to generate and control force for a high velocity throw. If there is a decrease in proximal stability through the core, the force generated distally cannot be properly controlled and may have contributed to this overuse injury.[23] The subject's mechanism of injury does not match with the extension and rotation mechanism typically seen with spondylolysis.[12] However, it is hypothesized that a lack of core stability during the eccentric control of this high velocity end range rotation is capable of generating enough shearing force on the pars interarticularis to lead to injury in this subject.

EXAMINATION

The results of the initial examination can be found in Tables 1 and 2. The examination was performed following six weeks of rest, bracing, and physician clearance to resume rehabilitation. The subject denied any neural symptoms or muscle pain. On day of examination, he reported localized, sharp, right-sided lumbar pain on the NPRS as 0-3/10 at rest over the prior few days and reported 8/10 with follow through of a lacrosse pass, which had last been attempted two months prior. The subject's initial Modified Oswestry Disability Index (ODI) was 16%.

There is no gold standard for evaluation of core strength. Kibler has previously described the importance of evaluating strength in the functional position in which the muscles work, and more specifically evaluating core strength through examination of the quality of movement and motor patterns.[23] Single leg stance and a single leg squat are two options described, and deviations such as a Trendelenberg posture and an internally or externally rotated limb during movements may suggest proximal core weakness through an inability to control the movement.[23]

Postural analysis revealed an excessive anterior pelvic tilt, bilateral external rotation of femurs, internal rotation of tibias, and eversion and forefoot abduction. Bilateral scapular protraction and humeral internal rotation were also noted with quiet stance, most likely in part due to decreased length in pectoralis major musculature. Gait analysis revealed overpronation and forefoot abduction with limb loading along with Trendelenberg sign bilaterally.

Functional movement analysis revealed genu valgum and ankle overpronation with body weight squat, poor hip and ankle control with a single leg squat, and avoidance of lumbar flexion picking up a weight from the ground. With bilateral shoulder flexion, excessive and compensatory extension was noted through thoracic and lumbar spine, most likely secondary to decreased flexibility of latissimus dorsi.

Range of motion (ROM) and strength measures revealed limitations throughout the trunk and lower quarter. The most significant flexibility impairments were seen through his hamstrings and hip flexors. Rotation through lumbar and thoracic spine was limited and mildly painful. The most significant strength impairments were seen in the hip abductors and extensors, trunk flexors, and scapular stabilizers.

Table 1. *Scores on Functional and Subjective Scales.*

	Baseline Week 1 Session 1	Week 7 Session 10	Post Intervention Week 10 Session 14
ODI	16%	8%	0%
NPRS	8/10	3/10	0/10
	Abbreviations: ODI, modified oswestry disability index; verbal NPRS, numerical pain rating scale		

Table 2. *Flexibility and Muscle Strength.*

	Flexibility*			
	Baseline Week 1 Session 1		**Post Intervention Week 10 Session 14**	
	left	**right**	**left**	**right**
Hip Flexors	fair	fair	good	good
Hip Extensors	fair	fair	good	good
Piriformis	fair	fair	good	good
Quadriceps	good	good	good	good
Hamstrings	poor	poor	fair	fair
Gastrocnemius	fair	fair	good	good
	Manual Muscle Testing (MMT)			
	Baseline Week 1 Session 1		**Post Intervention Week 10 Session 14**	
Hip Flexors	4-/5	4-/5	5/5	5/5
Hip Abductors	3+/5	3+/5	5/5	5/5
Hip Extensors	4-/5	4-/5	5/5	5/5
Knee Extensors	4/5	4/5	5/5	5/5
Knee Flexors	4/5	4/5	5/5	5/5
Ankle PF	4-/5	4-/5	5/5	5/5
Trunk Flexion	3+/5		5/5	
Trunk Extension	3+/5		5/5	
Trunk Rotation	3+/5	3+/5	5/5	5/5
Middle Trapezius	3+/5	3+/5	4+/5	4+/5
Lower Trapezius	3/5	3/5	4+/5	4+/5
Shoulder ER	4-/5	4-/5	5/5	5/5

Abbreviations: PF, plantarflexion. ER, external rotation *interpretation: poor= severe limitation; fair= moderate limitation, good= within functional limits.

CLINICAL IMPRESSION #2

The subject presented to PT with a clinical history consistent with a chronic biomechanical injury, as the subject's symptoms were consistently reproducible with a specific movement pattern and had occurred in the same location over the course of several years when sports were resumed. Imaging by MRI confirmed right sided L5 spondylolysis. Although there was a prognostic concern with the lack of success with PT in the past, it did not appear that former PT interventions successfully addressed any transverse plane movement or sports specific activity. Therefore, while past PT in combination with rest and bracing was able to decrease symptoms enough to allow subject to resume sport activities, reinjury occurred soon after resuming repetitive throwing movements.

The patient's lower quarter findings were consistent with what is typically seen in a subject presenting with spondylolysis, including tightness observed through hip flexor and hamstrings musculature, weakness through abdominals and gluteals, and excessive anterior pelvic tilt .[1,3,12,15,26] Based on these examination findings, it was determined that PT should address not only core and hip strength and hamstring flexibility, as was done in the past and is supported in the literature, but also to individualize the treatment and consider the entire kinetic chain and demands of sport when formulating the rehabilitation plan of care. Incorporating transverse plane movements into a plan of care for a subject with spondylolysis is uncommon in the literature and discouraged by some.[1,26] However, as the subject had just been braced for six weeks and his symptoms were controlled at rest, it was critical to incorporate multiplanar muscle activation and movement patterns in a stepwise manner to allow for full return to sport and prevention of reinjury.

INTERVENTION

The subject attended a total of 14 visits over the course of 10 weeks. He initially attended therapy two times per week for the first five weeks, then transitioned to one time per week as the plan of care progressed, with the 13th and 14th visits occurring two weeks apart. Interventions included therapeutic exercise and motor function training, operationally defined by the APTA in the Guide to Physical Therapist Practice.[27] Therapeutic exercise included aerobic capacity conditioning, flexibility exercises, neuromotor development training, and strength, power, and endurance training for trunk and limb muscles. Motor function training included balance training, motor control training, neuromuscular education, and task-specific performance training.

Manual therapy was not included as part of the plan of care as subject had no complaints of any palpable trigger points or tenderness to palpation. Foam rolling was used at the beginning of every session to address thoracic joint mobility and address feeling of lower quarter "tightness", and the subject was encouraged to perform this prior to completing program outside of the clinic.

The treatment plan based on existing literature and consideration of sport aimed to: 1) decrease subjective symptoms as measured via the ODI and NPRS; 2) correct soft tissue and joint abnormalities thought to contribute to injury; 3) address neuromuscular control of core musculature through multiplanar movements; and 4) return subject to sport at pre-injury level.

The progression through the phases of this program resembled the stepwise pattern outlined previously by Wilk for the rehabilitation of the overhead throwing athlete, broken into an acute, intermediate, and advanced phase.[22] Progression to the next phase was dictated by completion of the previous program with maintenance of core stability and symptoms remaining at a 2/10 or less during completion and following the program (Table 3).

Core stability for this patient was defined according to Kibler's previously published definition, "the ability to control the position and motion of the trunk over the pelvis and leg to allow optimum production, transfer and control of force and motion to the terminal segment in integrated kinetic chain activities."[23,p. 189] If the patient appeared to lose core stability and assume faulty movement patterns that could lead to injury or a decrease in force control – including an excessive anterior pelvic tilt, genu valgum, or tibial internal rotation, the exercise was stopped and the patient was cued by the physical therapist to correct the pattern.

The three phases of treatment, outlined below, focused on maintaining core stability with a gradual increase in difficulty, velocity, and amplitude of movement in all three planes of motion. The first phase of treatment addressed joint and soft tissue abnormalities and focused on isolated muscle strengthening. The second phase challenged the subject through compound, rotational kinetic chain movements. The third phase of treatment progressed to more dynamic, loaded, and advanced sport movements. There is scarce research available for rehabilitation of the lacrosse athlete.[19,21,28] However, the similarities between a baseball pitch and a lacrosse throw with regards to transfer of energy through the kinetic chain and movement pattern made it pragmatic to use established rehabilitation guidelines for the overhead athlete for the treatment of this subject.[22]

Phase 1-Addressing joint and soft tissue abnormalities, isolated strengthening

The initial phase of intervention was similar to those previously described in the literature. The goal of the initial phase was to decrease pain at rest and with activities of daily living (ADLs). This was done through mobility exercises, stretches, and isolated trunk and lower extremity strengthening in frontal, sagittal, and transverse planes for motor control purposes.

Flexibility training included stretches for the pectoralis major, latissimus dorsi, hamstrings, and gastrocnemius muscle groups to address impairments found during evaluation. It was hypothesized that a lack of flexibility in these muscles may have contributed to increased stress on the lumbar spine during sport due to changes in kinetic chain mechanics. Similar to a baseball pitcher during the cocking phase of throwing, maximum external rotation of the glenohumeral joint may be needed to successfully

Table 3. *Phases of Intervention.*

Phase 1		Phase 2		Phase 3	
Addressing joint and soft tissue abnormalities		Rotational, compound movements		Dynamic, loaded, and advanced movements	
DKTC/SKTC	5 x 10 seconds	Single leg RDLs with isometric hold	20 x 5 seconds	Chops/ Reverse Chops	2 x 10
PPT	15 x 5 seconds	90/90 abdominal isometrics	3 x 30 seconds	Medicine ball rotational throws in various positions	3 x 30 seconds full kneel 3 x 30 seconds standing
PPT with marching	2 x 10 reps	Pallof press (with rotation)	2 x 20	Goblet squats	3 x 12
Clams	2 x 15 reps	Multiplanar rhythmic stabilization drills	2 x 30 seconds 2 x 30 seconds	Plank activities	3 x 30 - 45 seconds
S/L thoracic mobility	2 x 10 reps	Wall slides with core stabilization	2 x 10	Banded quadruped thoracic mobility	2 x 10 with blue resistance band
Alternating isometrics in transverse plane	3 x 30 seconds	Dead bugs	2 x 10	Lateral band walks with heels elevated	2 x 50 feet with blue resistance band
Stretching for pectoralis, latissimus dorsi, hamstrings, and gastroc	3 x 30 seconds	Russian Twists	2 x 20	Plyometrics	5 – 10 minutes
Foam rolling thoracic spine and lower quarter	5 minutes	Elliptical for CV endurance	10 minutes	Running for CV endurance	10 minutes
Cycling for CV endurance	10 minutes				

Abbreviations: DKTC, double knee to chest; SKTC, single knee to chest; PPT, posterior pelvic tilt; Tra, transverse abdominus; S/L, sidelying; RDL, Romanian dead lift; CV, cardiovascular

complete a high velocity lacrosse throw.[29,30] The need for full thoracic spine mobility in the transverse and sagittal planes and good pectoralis and latissimus dorsi flexibility is necessary to complete rotation without compensation from other parts of the kinetic chain, such as the lumbar spine.[23,28]

Isolated core recruitment was important to establish as soon as possible due to the alleviating effects of increased intraabdominal pressure on vertebral stresses, especially on the pars interarticularis.[10,20] Isolated core recruitment was also important to establish early in treatment for this patient to increase the subject's ability to establish and identify pelvic neutral. Kinesthetic and proprioceptive awareness of the lumbar spine with simple movements, such as a posterior pelvic tilt (PPT), PPT with alternating leg marches (Figure 1), and alternating isometrics in the transverse plane (Figure 2), were key to establish foundational neuromuscular control for muscle recruitment to stabilize the lumbar spine before progressing to more functional movements.[21,28,31,32]

It was important that the subject did not lose this neuromuscular control and revert to dysfunctional movement patterns such as spinal rotation occurring on an anteriorly tilted pelvis, which may cause more stress to the original fracture site. The subject reported good compliance with completion of this program every day outside of the clinic.

Figure 1. *Posterior pelvic tilt with alternating leg march.*

Figure 2. *Alternating isometrics in transverse plane.*

Phase 2-Rotational, compound movements

The second phase of intervention focused around maintaining core stability with more advanced movements. Secondary to the correlation between hamstring tightness and spondylolysis lengthening the hamstrings was an important part of this intervention.[1,3,13] In the first phase, this was addressed with a static stretch. However, in the literature it is suggested that eccentric strengthening of the hamstrings may be more effective for increasing flexibility than static stretching, and this was introduced during phase two (Figure 3).[33,34]

Increasing challenge was put on the deep and superficial abdominal musculature, starting isometrically though abdominal holds (Figure 4), supine stability with alternating arms and legs, anti-rotation chest press (Figures 5 and 6), and rhythmic stabilization drills in half kneeling, full kneeling, and standing. When the subject reported decreased challenge and maintenance of core stability was observed with movements, isotonic movement through the trunk was added in all three planes of movement. Overhead movement was added during wall slides with a focus on maintaining core stability and preventing compensatory spinal extension, as linking

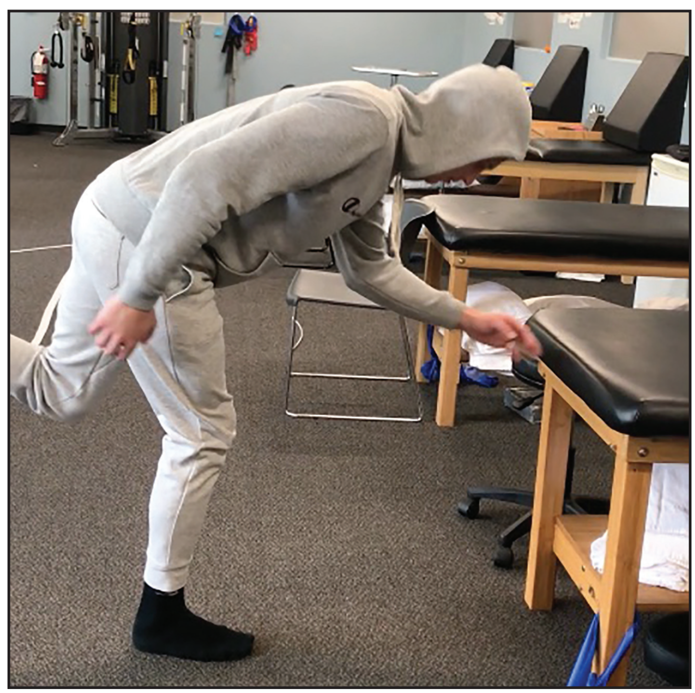

Figure 3. *Single leg Romanian dead lift with 5 second isometric hold.*

Figure 4. *90/90 abdominal isometric hold completed for time (30 seconds x 3).*

the shoulder joint to the core and lower extremity is crucial for optimal kinetic chain function (Figure 7).[22,28,31] The goal of these progressions was to enhance neuromuscular control and increase coordination, strength and stability of core musculature in pain free, controlled environments.[21,22,32] The subject's pain level and ability to maintain core stability were used to dictate the speed of progression.

Stretching and mobility exercises from Phase 1 were also completed during Phase 2. The subject continued to report good compliance outside of the clinic. Stretches were performed daily, and all other aspects of the program were completed five days per week.

Phase 3-Dynamic, loaded, and advanced movements

As the subject has reported reinjury during the eccentric control following a lacrosse throw, multiplanar movements with increasing challenge were the focus of the Phase 3. The goals of this phase were to increase the subject's ability to maintain good trunk control through full spinal rotational range of motion with increasing demands. Thoracic mobility drills completed in earlier phases were progressed

Figure 5. *Pallof press: with resistance band, subject presses band straight out away from body and returns to starting position.*

with a resistance band through the transverse plane pattern (Figure 8) to prepare musculature to stabilize through all available range of motion prior to adding more challenging functional activities.

Upper extremity plyometrics were added in this phase through tall kneeling and standing rotational medicine ball throws (Figures 9 through 12). Challenge was increased slowly by increasing the velocity, degree of rotational range of motion, and external load placed upon the spine through progressive weight and arm distance away from trunk. As the patient's MOI was during eccentric control following a rotational pattern, thus, the focus of the exercise was core stability during the amortization and eccentric phases of the throw.[22] It was important

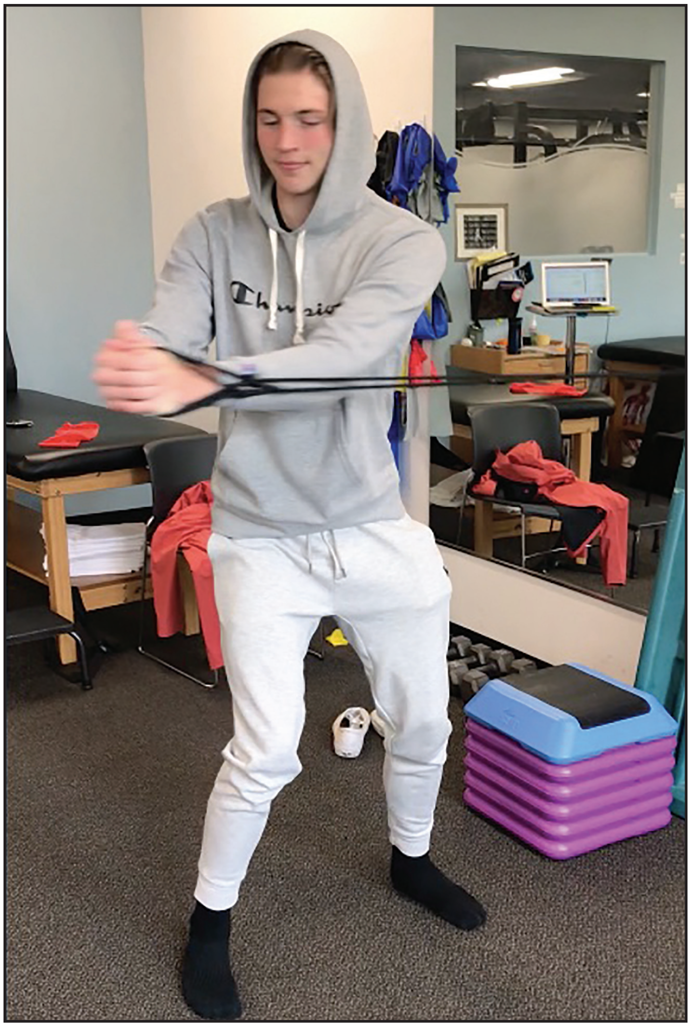

Figure 6. *Pallof press with rotation: same as previous image but after subject presses band away from body, subject rotates away from anchor, rotates back in, and returns to starting position.*

Figure 7. *Wall slides with core stabilization – from this position subject slides up wall while maintaining core stability.*

to choose exercises that would translate well into optimal core stability during athletic performance. Increasing the challenge of the exercise through extremity movements and focusing on sport-specific movements may translate better to athletic activities than training on unstable surfaces, and thus was the focus of progressions.[22,32,35,36]

Proprioceptive neuromuscular facilitation (PNF) activities, such as chops and lifts, are also recommended in the literature for core stabilization during rehabilitation of the athlete.[21–23] These activities should be completed through a pain free range of motion, which should progress through the entire available range of motion as the movement pattern is mastered.[22] This subject completed chops and lifts using a cable column, starting in a half kneeling position to focus on maintaining core stability through a rotational pattern. As this became easier, the subject moved to standing to allow integration of the lower extremities into the kinetic chain through the movement pattern (Figure 13).

During this phase, the subject also initiated impact activities through lower extremity plyometric training and running. The subject reported no symptoms with any impact activities during sessions and outside of the clinic.

At the end of seven weeks, the subject initiated return to sport activities. He participated in non-contact drills for one week, and following clearance from the physical therapist participated in one week of full practice with contact. At this point, game play

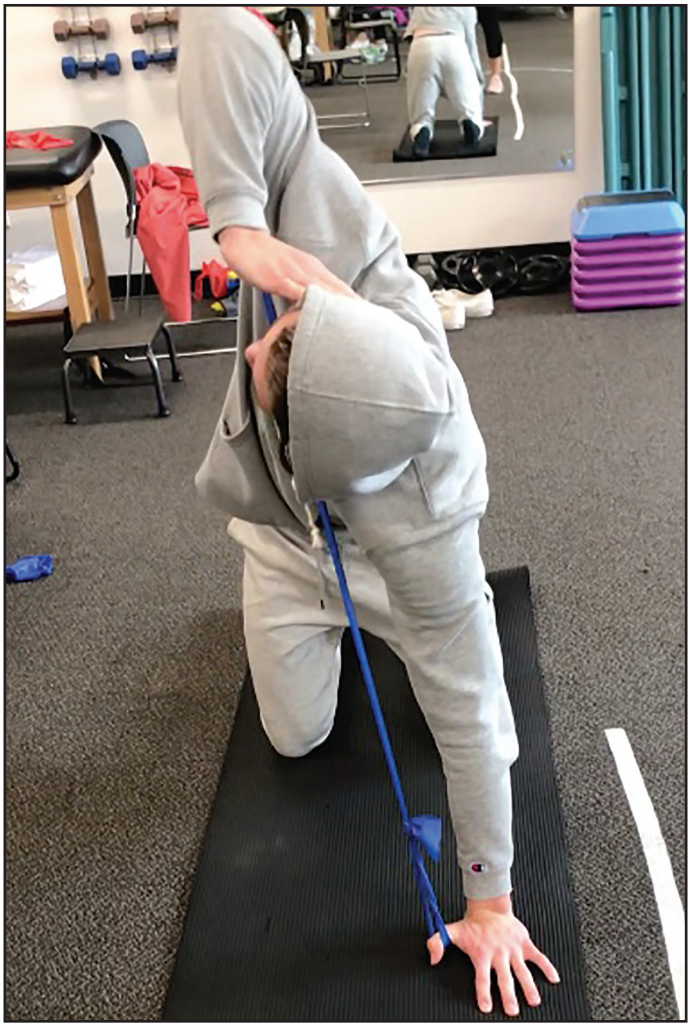

Figure 8. *Banded quadruped thoracic mobility.*

Figure 9. *Medicine ball rotational throws in full kneeling (catch).*

was initiated with the subject instructed to remove himself from game play if he felt more than 2/10 pain. He was able to play unrestricted without an increase in symptoms. The subject participated in the remainder of the season without any setbacks or flareups of symptoms.

OUTCOMES

The subject was able to return to lacrosse after eight weeks of physical therapy and completed the remaining 10 weeks of the season without reinjury. He was discharged from formal physical therapy after 10 weeks with an ODI score of 0%, achieving the minimally clinically important difference (MCID) of 12.8%.[37] The ODI is a valid tool and has high test retest reliability.[38,39]

The subject's strength and muscle length at discharge were markedly improved over the examination (Table 1). Although there is no MCID or minimal detectable change (MDC) established for strength testing, MMT has been shown to be a valid and reliable clinical test of muscle strength.[40]

The subject noted 0/10 pain at rest and with all sport activity, and occasional soreness following sport not exceeding 2/10 which was relieved with stretching and foam rolling. The subject also reported no fear of movement and increased confidence in his back during sport. He continued to perform a maintenance program as a warm up prior to initiating any sport activity (Appendix A).

DISCUSSION

It is clear in the literature that conventional rehabilitation, centering around isolated lower extremity flexibility and core strengthening in the sagittal and frontal planes, serves as a foundation in the

Figure 10. *Medicine ball rotational throws in full kneeling (amortization phase).*

Figure 11. *Medicine ball rotational throws in full kneeling (concentric throw).*

successful conservative management of many athletes with spondylolysis, with return to sport rates between 75% and 96%.[1,2,4,11,13,14,24,25] However, it is unclear why some athletes are unable to return to sport following conservative treatment and may undergo a complicated surgery that also has success rates in the 90% range. The current case describes the successful rehabilitation of a lacrosse player who had failed to return to play multiple times following a standard PT approach. His symptoms occurred with rotational movements, and prior intervention programs did not incorporate transverse and multiplanar activities. Therefore, it was hypothesized continued deficits in strength and lack of neuromuscular stabilization, especially through trunk musculature, as noted in his physical examination, were potential contributors to his ongoing symptoms. The addition of higher-level functional activities in all three planes of motion to the plan of care led to a successful outcome.

Lacrosse is not commonly associated with spinal stress fractures, although it shares several biomechanical similarities with sports that are associated with spondylolysis such as baseball and tennis.[14,16,30] Most notably is the requirement to transfer energy from the lower extremities through the trunk to the upper extremities to complete a high velocity, high amplitude movement through a pattern of spinal extension and rotation with repetition. The literature reports that bracing and rest from sport is necessary to allow for proper bony healing by minimizing intervertebral motion and promoting bony and fibrous healing.[2,4,24,41] However once this healing occurs, it is important to properly prepare the athlete for sport resumption after a period of inactivity, ideally utilizing a comprehensive rehabilitation program that addresses found impairments in all planes.

Figure 12. *Medicine ball rotational throws in standing.*

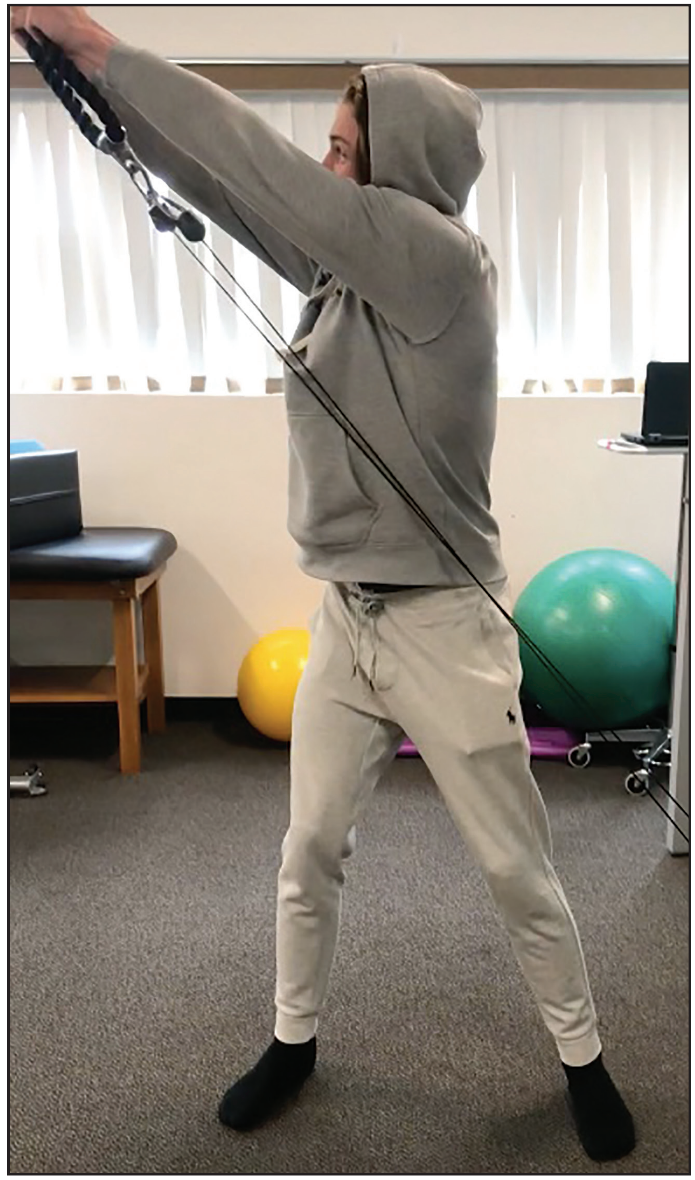

Figure 13. *Reverse chops completed with cable column.*

The authors considered the specific demands of the subject's sport, particularly the high velocity extension with rotation movement when designing a rehabilitation program for this subject. It is possible that return to play rates, in lacrosse as well as other similar sports, may be further improved by incorporating more transverse plane loaded activities into the plan of care.

When conservative treatment fails, surgery may be considered in these young athletes. Following surgical intervention around 90 percent of athletes return to play.[11,24] However, the complication rate following surgery to address spondylolysis is high. A recent systematic review found that of 75 subjects that underwent surgical intervention, 15 had peri-operative complications including nonunion, screw fracture, wire breakage, and radiculopathy.[11] With a complication rate this high, conservative treatment should be exhausted before pursuing surgical intervention. It is believed by the authors that a rehabilitation program designed with consideration of the specific mechanics of sport may increase the likelihood of successful conservative management and avoid surgical intervention.

As with any case report, there are limitations to the applicability of this research to future subjects. It cannot be stated with certainty which, if any, of the described interventions had an impact on the successful outcome of this subject. It is possible that bony healing improved more during this bout of conservative care secondary to the continued maturation of the subject's skeletal system. While still present, incident spondylosis rates significantly decrease after the age where bony maturity typically occurs.[2,3,24,42] However, as the subject has had multiple bouts of standard care without successful return to sport, the authors believe there may be merit to this multi-phase intervention. Future studies incorporating multiplanar movements and considering the kinetic chain are suggested.

CONCLUSION

This paper details the successful rehabilitation of an 18-year-old lacrosse player in returning to sport without reinjury, This case report demonstrates the efficacy of a rehabilitation program centered around multiplanar movements and with consideration of the kinetic chain and sport specific demands in a lacrosse player with recalcitrant symptomatic spondylolysis. Although the authors cannot establish whether this intervention was the reason for successful return to play after three previous failed bouts of rehabilitation, future controlled trials should examine the effectiveness of incorporating transverse plane movements in a neutral lumbopelvic position in athletes with spondylolysis.

REFERENCES

1. Lawrence KJ, Elser T, Stromberg R. Lumbar spondylolysis in the adolescent athlete. *Phys Ther Sport*. 2016;20:56-60.
2. Ebraheim N, Elgafy H, Gagnet P, Andrews K, Kern K. Spondylolysis and spondylolisthesis: a review of the literature. *J Orthop*. 2018;15(2):404-407.
3. Tsirikos AI, Garrido EG. Spondylolysis and spondylolisthesis in children and adolescents. *J Bone Joint Surg Br*. 2010;92-B(6):751-759.
4. Sakai T, Tezuka F, Yamashita K, et al. Conservative treatment for bony healing in pediatric lumbar spondylolysis. *Spine*. 2017;42(12):E716-E720.
5. Harvey CJ, Richenberg JL, Saifuddin A, Wolman RL. Pictorial review: the radiological investigation of lumbar spondylolysis. *Clin Radiol*. 1998;53(10): 723-728.
6. Belfi LM, Ortiz AO, Katz DS. Computed tomography evaluation of spondylolysis and spondylolisthesis in asymptomatic patients. *Spine*. 2006;31(24):E907-E910.
7. Fredrickson BE, Baker D, McHolick WJ, Yuan HA, Lubicky JP. The natural history of spondylolysis and spondylolisthesis. *J Bone Joint Surg Am*. 1984;66(5):699-707.
8. Micheli LJ, Wood R. Back pain in young athletes. Significant differences from adults in causes and patterns. *Arch Pediatr Adolesc Med*. 1995;149(1): 15-18. h
9. Selhorst M, Fischer A, Graft K, et al. Long-term clinical outcomes and factors that predict poor prognosis in athletes after a diagnosis of acute spondylolysis: a retrospective review with telephone follow-up. *J Orthop Sport Phys Ther*. 2016;46(12): 1029-1036.
10. Dietrich M, Kurowski P. The importance of mechanical factors in the etiology of spondylolysis-a model analysis of loads and stresses in human lumbar spine. *Spine (Phila Pa 1976)*. 1985;10(6): 532-542.
11. Overley SC, McAnany SJ, Andelman S, et al. Return to play in adolescent athletes with symptomatic spondylolysis without llisthesis: a meta-analysis. *Glob Spine J*. 2018;8(2):190-197.
12. McCleary MD, Congeni JA. Current concepts in the diagnosis and treatment of spondylolysis in young athletes. *Curr Sports Med Rep*. 2007;6(1):62-66.
13. Sys J, Michielsen J, Bracke P, Martens M, Verstreken J. Nonoperative treatment of active spondylolysis in elite athletes with normal X-ray findings: Literature review and results of conservative treatment. *Eur Spine J*. 2001;10(6):498-504.
14. Ruiz-Cotorro A, Balius-Matas R, Estruch-Massana A, Vilaró Angulo J. Spondylolysis in young tennis players. *Br J Sports Med*. 2006;40(5):441-446.
15. Motley G, Nyland J, Jacobs J, Caborn DNM. The pars interarticularis stress reaction, spondylolysis, and spondylolisthesis progression. *J Athl Train*. 1998;33(4):351-358.
16. Mercer J, Nielson J. Description of phases and discrete events of the lacrosse shot. The Sport Journal. http://thesportjournal.org/article/description-of-phases-and-discrete-events-of-the-lacrosse-shot/. Published 2012.
17. Vincent HK, Chen C, Zdziarski LA, Montes J, Vincent KR. Shooting motion in high school, collegiate, and professional men's lacrosse players. *Sport Biomech*. 2015;14(4):448-458.

18. Vincent HK, Chen C, Zdziarski LA, Montes J, Vincent KR. Shooting motion in high school, collegiate, and professional men's lacrosse players. *Sport Biomech*. 2015;14(4):448-458.
19. Wasser JG, Chen C, Vincent HK. Kinematics of shooting in high school and collegiate lacrosse players with and without low back pain. *Orthop J Sport Med*. 2016;4(7):232596711665753.
20. Crisco JJ, Panjabi MM, Yamamoto I, Oxland TR. Euler stability of the human ligamentous lumbar spine. Part II: Experiment. *Clin Biomech*. 1992;7(1):27-32.
21. Vincent HK, Vincent KR. Core and back rehabilitation for high-speed rotation sports. *Curr Sports Med Rep*. 2018;17(6):208-214.
22. Wilk KE, Arrigo CA, Hooks TR, Andrews JR. Rehabilitation of the overhead throwing athlete: there is more to it than just external rotation/internal rotation strengthening. *PM&R*. 2016;8(3S):S78-S90.
23. Kibler W Ben, Press J, Sciascia A. The role of core stability in athletic function. *Sports Med*. 2006;36(3):189-198.
24. Grazina R, Andrade R, Santos FL, et al. Return to play after conservative and surgical treatment in athletes with spondylolysis: A systematic review. *Phys Ther Sport*. 2019;37:34-43.
25. Donaldson LD. *Spondylolysis in Elite Junior-Level Ice Hockey Players.* Vol 6.; 2014:356-359.
26. Álvarez-Díaz P, Alentorn-Geli E, Steinbacher G, Rius M, Pellisé F, Cugat R. Conservative treatment of lumbar spondylolysis in young soccer players. *Knee Surgery, Sport Traumatol Arthrosc*. 2011;19(12):2111-2114.
27. American Physical Therapy Association. *Guide to Physical Therapist Practice 3.0.* http://guidetoptpractice.apta.org/content/current. Accessed July 13, 2019.
28. Vincent HK, Vincent KR. Rehabilitation and prehabilitation for upper extremity in throwing sports: emphasis on lacrosse. *Curr Sports Med Rep*. 2019;18(6):229-238.
29. Suzuki Y, Muraki T, Sekiguchi Y, et al. Influence of thoracic posture on scapulothoracic and glenohumeral motions during eccentric shoulder external rotation. *Gait Posture*. 2019;67:207-212.
30. Miyashita K, Kobayashi H, Koshida S, Urabe Y. Glenohumeral, scapular, and thoracic angles at maximum shoulder external rotation in throwing. *Am J Sports Med*. 2010;38(2):363-368.
31. Kibler W Ben, Thomas SJ. Pathomechanics of the throwing shoulder. *Sports Med Arthrosc*. 2012;20(1):22-29.
32. Huxel Bliven KC, Anderson BE. Core stability training for injury prevention. *Sports Health*. 2013;5(6):514-522.
33. Nelson RT. A comparison of the immediate effects of eccentric training vs static stretch on hamstring flexibility in high school and college athletes. *N Am J Sports Phys Ther*. 2006;1(2):56-61.
34. O'Sullivan K, McAuliffe S, DeBurca N. The effects of eccentric training on lower limb flexibility: a systematic review. *Br J Sports Med*. 2012;46(12):838-845.
35. McGill SM, Karpowicz A. Exercises for spine stabilization: motion/motor patterns, stability progressions, and clinical technique. *Arch Phys Med Rehabil*. 2009;90(1):118-126.
36. Behm DG, Drinkwater EJ, Willardson JM, Cowley PM. The use of instability to train the core musculature. *Appl Physiol Nutr Metab*. 2010;35(1):91-108.
37. Lee GW, Lee SM, Ahn MW, Kim HJ, Yeom JS. Comparison of surgical treatment with direct repair versus conservative treatment in young patients with spondylolysis: A prospective, comparative, clinical trial. *Spine J*. 2015;15(7):1545-1553.
38. Fisher K, Johnston M. Validation of the Oswestry Low Back Pain Disability Questionnaire, its sensitivity as a measure of change following treatment and its relationship with other aspects of the chronic pain experience. *Physiother Theory Pract*. 1997;13(1):67-80.
39. Irmak R, Baltaci G, Ergun N. Long term test-retest reliability of Oswestry Disability Index in male office workers. *Work*. 2016;53(3):639-642.
40. Cuthbert SC, Goodheart GJ. On the reliability and validity of manual muscle testing: a literature review. *Chiropr Osteopat*. 2007;15(1):4.
41. El Rassi G, Takemitsu M, Woratanarat P, Shah SA. Lumbar spondylolysis in pediatric and adolescent soccer players. *Am J Sports Med*. 2005;33(11):1688-1693.
42. Sutton JH, Guin PD, Theiss SM. Acute lumbar spondylolysis in intercollegiate athletes. *J Spinal Disord Tech*. 2012;25(8):422-425.

Appendix A. *Maintenance program.*

Exercise	Set/Rep Scheme
Foam Rolling	5-10 minutes
DKTC	5 x 10 seconds
Figure 4 Stretch	2 x 30 seconds
Dead Bug	2 x 10
Russian Twist	2 x 20
Full Plank with March	2 x 20
Lateral Walking Heels Elevated	2 x 25 feet Black resistance band
Goblet Squat	2 x 15 x 25lbs
Lifts/Chops	2 x 10 x 20lbs
Med Ball Rotational Throws	3-4kg med ball 2 x 10 close to body 2 x 10 arms extended
Quadruped Rocking	20

Abbreviations: DKTC, double knee to chest;